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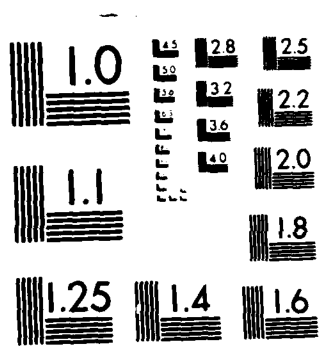

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During the period, Dec. 1, 1981 through Nov. 30, 1982, the group at the Laboratory for Image and Signal Analysis of The University of Texas made 13 presentations, published 10 papers (5 in journals and 5 in conference proceedings) and prepared 5 technical reports. At the same time the group devoted its efforts to four areas described briefly in the report: (1)Volumetric Descriptions of Objects from Multiple Views (2)Contour Registration by Shape Specific Points (3)Detection of Edges Using Range Information (4)A Normalized Quadtree Representation.

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Scientific Report for the period
1 December 1981 - 30 November 1982
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The University of Texas at Austin
Department of Electrical Engineering
Austin, Texas 78712

Principal Investigator: Professor J. K. Aggarwal

SCIENTIFIC REPORT

During the period, December 1, 1981 through November 30, 1982, our group made 13 presentations and published 10 papers (5 in journals and 5 in conference proceedings). In addition, our group published 5 technical reports. The group also prepared 6 papers which have been accepted for journal publication. A listing of these presentations and publications is provided at the end of this report.

The group devoted its efforts to four areas briefly described in the next section of this report:

1. Volumetric Description of Objects from Multiple Views

Volumetric models have been the basis of numerous three-dimensional object modelling systems. The two major goals pursued in our work are, first, to lessen the dependence on feature point measurements in a structure from multiple views system, and second, to develop a descriptive three-dimensional object representation that was suitable for a dynamic process of volume refinement. The results are two fold: (i) a system has been developed which constructs a volumetric structure for an object from a sequence of occluding contours, and (ii) an algorithm has been formulated for the representation, and refinement of this structure.

The occluding contours with viewpoint specifications from a dynamic image are analyzed to initially form and continually update a description of the three-dimensional object generating the contours. The description is a bounding volume for the object and is successively refined to yield finer approximations to the actual object. Of course, from the silhouettes that form the occluding contours it is not possible to resolve certain kinds of concavities. In particular, object surface points for which every tangent line (in the tangent plane, any line that contains the given surface point) also intersects the object at some non-surface point cannot be resolved using silhouettes. However, the class of objects that can be described exactly is large, and in fact, the object surface may have saddle points and holes.

Clearly, to analyze the structure of objects a system must provide a representation scheme. For three-dimensional objects many different schemes have been proposed and used. The details of the representations usually are determined either by the data acquisition techniques or by the ultimate application of the system, with an important problem being the development of methods for transforming between structures of the first type and structures of the second type. The volume segment representation described in our work has been developed to facilitate the acquisition of three-dimensional information dynamic images. The main attributes of the volume segment representation are that it is easy to update (as required by the continual refinement), maintains fine surface detail, simplifies the point inclusion test, and can be readily transformed into a surface representation.

For these reasons our work presented provides an excellent basis for further research. In particular, the work is appropriate to industrial automation applications. For example, selecting one of several parts on a conveyor using the views taken from several cameras fixed along the line of travel, or in conjunction with a manipulator arm that could successively reposition a part until an adequate approximation was derived. In such applications there are usually fixed sets of possible objects from which an unknown object must be recognized, implying the need for a representation scheme suitable for creating a library of possible objects, describing the unknown sample and matching it to the library entries. Further research will be directed toward exploiting the methods developed here.

2. Contour Registration by Shape Specific Points

The registration of contours of objects is often an important aspect in many image processing systems. In the context of shape analysis, for example, it appears as a crucial step in important tasks such as image segmentation, analysis of time-varying imagery and binocular perception of depth. In image segmentation shape is often the basis for the detection and recognition of patterns such as lines, edges and corners and more general images of objects such as characters. In the analysis of dynamic scenes, it is necessary to track images of objects from one frame to the next in a sequence of time-varying images; and shape analysis is an important tool in this correspondence process. The correspondence of features is also a central issue in stereomapping where it is necessary to identify the parts of two pictures, taken from different view points, that represent the same object in the actual underlying scene. Thus shape matching has been motivated by a variety of applications and has led to a number of solutions. Shape analysis techniques depend on the model used to represent the relevant information in the image and the success of these techniques depends on how closely the model fits the actual situation. There is a profusion of literature relating to shape analysis as documented in C.3.

Our work is concerned with planar shapes and presents a new approach to shape matching based on the simple observation that matching is a much easier task when shapes are properly registered. Some of the advantages of this approach stem from the fact that registration allows the application of shape matching algorithms (e.g. template matching) that cannot otherwise be applied on shapes that are not registered. The present study thus advocates the use of spatial registration before matching and describes how registration of two planar figures can be achieved by computing, from the shape of each figure, points that are specific to the shape with respect to transformations of interest. These points can in fact be considered part of the shape even though they may be physically apart from it. The centroid is one example of such points.

Although specific or "special" points and lines such as the centroid and the major and minor axes have often been used in shape analysis, it was for the purpose of extracting characteristic features to describe shapes independently of the coordinate system. For example, Hu represented visual patterns such as characters by lower-order two-dimensional moments that are invariant under general linear transformations. Then a simple clustering procedure was used to classify the various unknown patterns. Thus the moments method transforms patterns into a set of scalar features that lose the spatial organization of the patterns.

The technique reported in our study computes shape specific points in the spatial or picture domain for the purpose of registration. The present technique is translation, rotation and scale change independent. The transformation to register one figure to another is easily recovered. After figures are registered, various matching algorithms can be used to check how closely their boundaries match. More details are given in C.3.

3. Detection of Edges Using Range Information

Range data provide an important source of 3-D shape information. Range data implicitly contain information about the shape of the surface of objects because the coordinates of points on the surface of these objects can be easily recovered from them. Moreover, they can be used to extract jump boundaries which correspond to occluding boundaries of objects in a scene, and "edges" which are points that lie on the intersection of two regions on the surface with significantly different parameters (e.g. the edge between two visible faces of a cube). Jump boundaries and edges are important cues in the segmentation process because they delineate the extent of surfaces. These boundaries and edges are intrinsic properties of the surface of objects unlike edges in "intensity" images derived from range data. For example one may create an image by using a range coding convention in which dark = near and light = far. The image is then enhanced to compensate for low frequency trends present in systems which have shallow line of sight. Finally, edges are computed using the Sobel operator. In our work we are concerned with edges that actually occur on the surface of objects in the scene. Although simple methods have been devised that are successful at computing jump boundaries, the problem of finding edges is a much more delicate problem which has not received enough attention. Here, we are mainly interested in range data obtained from sensors such as the one at SRI International. The major problem with this type of range finder is that the accuracy of the measurements depends on the power of the signal that reaches the receiver. The accuracy of the range data is therefore dependent on the parameters of the system (transmitted beam power and receiver variables) and on the characteristics of the target (orientation and reflectance of its surface and actual distance from the sensor). System parameters and target characteristics affect accuracy because they affect the strength of the signal that returns to the sensor. It should be pointed out that we do not restrict ourselves to the SRI laser sensor.

Our goal in this study is to design and analyze a procedure for detecting edges using range information that has low sensitivity to noise. We also want to relate the range measurement accuracy to the problem of detecting edges. The input to this procedure includes range data and a model for range measurement error. Basically, this procedure determines the best partition of a neighborhood of each point in the scene into two contiguous regions. Planes are fitted to these regions and a measure of the goodness of fit is calculated. The measure should imbed all the knowledge that one has about range measurement accuracy, so that the resulting value can be used to select the "best" partition. Subsequent analysis can then extract significant edges from the scene. Although we are fitting planes to small patches on the surface of objects, we are not looking for planar surfaces. We are interested in determining the presence or absence of an edge at points on the surface of objects. Preliminary results are reported in B.3 and C.4.

4. A Normalized Quadtree Representation

Quadtrees are hierarchical data structure used for compact representations of two-dimensional images. A quadtree is generated by dividing an image into quadrants and repeatedly subdividing the quadrants into sub-quadrants until each quadrant has uniform color (e.g. '1' or '0' in a binary image). The root of a quadtree corresponds to the image it represents. A node in a quadtree either is a leaf (terminal node) or has four son-nodes (non-terminal node). Each son-node is associated with a quadrant of the block corresponding to its father-node.

The advantage of the quadtree representation for images is that simple and well-developed tree traversal algorithms allow fast execution of certain operations such as superposition of two images, area and perimeter calculation, moments computation, etc. Other researchers have shown that the quadtree representation of images yields substantial data compression over a variety of source images. In their experiments, image compression ratio ranging between three to one and thirty-three to one were found, with five or six to one being the general compression factor.

However, the quadtree representation has certain disadvantages. The quadtree representation of an object in an image is heavily affected by its location, orientation and relative size. A small change in these parameters will generate different quadtrees. To eliminate the effect due to the translation of objects in an image, one defines a normal form for quadtrees. Assuming that the size of an image lies between 2^{N-1} and 2^N, the image is moved around a region of size 2^{N+1} to find a minimal cost quadtree in terms of the number of nodes. Other researchers assert that this quadtree representation is unique for any image over the class of translations. However, the problem arising from rotations and size change still remains.

In our research, we propose a representation scheme, the normalized quadtree representation, which is invariant to object translation, rotation and size change. Instead of generating a quadtree for the entire image, a normalized quadtree is generated for each object in the image. The object is normalized to an object-centered coordinate system, with its centroid as the origin and principal axes as coordinate axes, and then scaled to a standard size (a $2^N \times 2^N$ image). In this way, the normalized quadtree of an object is dependent only on the shape of the object, but not affected by its location, orientation or relative size. In other words, the normalized quadtree representation can be utilized as a shape descriptor. In addition, information related to the size, the position and the angle of the major principal axis of the object in the image may be retained enabling reconstruction of the object as it appeared in the image.

PRESENTATIONS, PROCEEDINGS AND PUBLICATIONS

A. Presentations

1. A. Mitiche and J. K. Aggarwal, "Detection of Edges Using Range Information," at the IEEE International Conference on Acoustics, Speech and Signal Processing, May 3-5, 1982, Paris, France.

2. W. N. Martin and J. K. Aggarwal, "Dynamic Scenes and Object Descriptions," at the IEEE International Conference on Acoustics, Speech and Signal Processing, May 3-5, 1982, Paris, France.

3. J. K. Aggarwal, "Dynamic Scene Analysis," at the NATO Advanced Study Institute on Image Sequence Processing and Dynamic Scene Analysis, June 1982, Braunlage, West Germany.

4. J. K. Aggarwal, At the Session on "3-D Motion Analysis" at the NATO Advanced Study Institute on Image Sequence Processing and Dynamic Scene Analysis, June, 1982, Braunlage, West Germany.

5. J. K. Aggarwal, "Three-dimensional Description of Objects," at the NATO Advanced Study Institute on Image Sequence Processing and Dynamic Scene Analysis, June 1982, Braunlage, West Germany.

6. J. K. Aggarwal, "Dynamic Scene Analysis - A Panel Discussion," at the NATO Advanced Study Institute on Image Sequence Processing and Dynamic Scene Analysis, July, 1982, Braunlage, W. Germany.

7. J. K. Aggarwal, "Dynamic Scene Analysis," at the Deutsche Forschung und Versuchsanstalt fur Luft-und Raumfahrt (DFLVR), Munich, West Germany, July 9, 1982.

8. J. K. Aggarwal, "Dynamic Scene Analysis," at the Bundeskriminal Amt (BKA), Wiesbaden, West Germany, July 16, 1982.

9. L. Mahaffey, L. S. Davis and J. K. Aggarwal, "Region Correspondence in Multi-Resolution Images Taken from Dynamic Scenes," at the Workshop on Multi-resolution Image Processing and Analysis, Leesburg, VA, July 19-21, 1982.

10. J. K. Aggarwal, "Dynamic Scene Analysis," at the Department of Electrical Engineering, Texas A & M University, College Station, TX, August 23, 1982.

11. J. A. Webb and J. K. Aggarwal, "Shape and Correspondence," at the Workshop on Computer Vision, Representation and Control, August 1982, Rindge, NH.

12. J. K. Aggarwal, "Three-Dimensional Information from Image and Motion Analysis," at McGill University, Department of Electrical Engineering, Montreal, Canada, Oct. 4, 1982.

13. J. K. Aggarwal, "Three-Dimensional Description of Objects and Dynamic Scene Analysis," at II Conference on Image Analysis and Processing, November 18, 1982, Selva di Fasano, Brindisi, Italy.

B. Papers

1. J. W. Roach, W. N. Martin, L. S. Davis, J. K. Aggarwal, "Survey: Representation Methods for Three-Dimensional Objects," Progress in Pattern Recognition, Vol. 1, Edited by L. N. Kanal and A. Rosenfeld, North Holland Publishing Company, 1981, pp. 377-391.

2. W. N. Martin, J. K. Aggarwal, "Analyzing Dynamic Scenes Containing Multiple Moving Objects," Image Sequence Analysis, Edited by T. S. Huang, Springer-Verlag, 1981, pp. 355-380.

3. A. Mitiche, J. K. Aggarwal, "Detection of Edges Using Range Information," Proceedings of International Conference on Acoustics, Speech and Signal Processing, May 3-5, Paris, France, pp. 1906-1911.

4. W. N. Martin, J. K. Aggarwal, "Dynamic Scenes and Object Descriptions," Proceedings of International Conference on Acoustics Speech and Signal Processing, May 3-5, 1982, Paris, pp. 859-862.

5. J. A. Webb and J. K. Aggarwal, "Shape and Correspondence," Proceedings of Workshop on Computer Vision Representation and Control, August 23-25, 1982, Rindge, NH.

6. J. K. Aggarwal, "Dynamic Scene Analysis," at the NATO Advanced Study Institute on Image Sequence Processing and Dynamic Scene Analysis, June 1982, Braunlage, W. Germany (Abstract only).

7. W. N. Martin and J. K. Aggarwal, "Volumetric Descriptions from Dynamic Scenes," Pattern Recognition Letters 1, (1982), pp. 107-113, December 1982.

8. A. Mitiche, B. Gil and J. K. Aggarwal, "On Combining Range and Intensity Data," Pattern Recognition Letters

1, (1982), pp. 87-92, December 1982.

9. J. A. Webb and J. K. Aggarwal, "Structure from Motion of Rigid and Jointed Objects," Artificial Intelligence, 19 (1982), pp. 107-130.

10. W. N. Martin and J. K. Aggarwal, "Extraction of Moving Object Descriptions via Differencing," Computer Graphics and Image Processing, No. 18, 1982, pp. 188-201.

C. Papers Prepared - To Appear

1. J. A. Webb and J. K. Aggarwal, "Shape and Correspondence," to appear in Computer Vision, Graphics and Image Processing.

2. W. N. Martin and J. K. Aggarwal, "Volumetric Descriptions of Objects from Multiple Views," to appear in IEEE Transactions on Pattern Analysis and Machine Intelligence.

3. A. Mitiche and J. K. Aggarwal, "Contour Registration by Shape Specific Points for Shape Matching," to appear in Computer Vision, Graphics and Image Processing.

4. A. Mitiche ano J. K. Aggarwal, "Detection of Edges Using Range Information," to appear in IEEE Transactions on Pattern Analysis and Machine Intelligence.

5. B. Gil, A. Mitiche and J. K. Aggarwal, "Experiments in Combining Intensity and Range Edge Maps," to appear in Computer Vision, Graphics and Image Processing.

6. J. K. Aggarwal and W. N. Martin, "Dynamic Scene Analysis," to appear in the Proceedings of the NATO-ASI, Braunlage, W. Germany.

D. Reports

1. B. Gil, A. Mitiche and J. K. Aggarwal, "Exeriments in Combining Intensity and Range Edge Maps," Technical Report No. TR-82-1, Laboratory for Image and Signal Analysis, The University of Texas at Austin, March 1982.

2. J. K. Aggarwal and W. N. Martin, "Dynamic Scene Analysis," Technical Report No. TR-82-3, Laboratory for Image and Signal Analysis, The University of Texas at Austin, September 1982.

3. A. Mitiche and J. K. Aggarwal, "Detection of Edges Using Range Information, Technical Report No. TR-82-4, Laboratory for Image and Signal Analysis, The

University of Texas at Austin, October 1982.

4. W. N. Martin and J. K. Aggarwal, "Volumetric Descriptions of Objects from Multiple Views," Technical Report No. TR-82-5, Laboratory for Image and Signal Analysis, The University of Texas at Austin, October 1982.

5. K. Palem, S. Yalamanchili, L. S. Davis, J. K. Aggarwal and A. J. Welch, "Image Processing Architecture: A Taxonomy and Survey," Technical Report No. TR-82-6, Laboratory for Image and Signal Analysis, The University of Texas at Austin, November 1982.

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